Progress towards Actinic Patterned Mask Inspection

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Outline

- Status (technical) of EUV Actinic Reticle Inspection program
- Xe –based LPP source as bright and reliable solution
  - Requirements
  - Choice of architecture
  - Current status
    - Radiance
      - Short bursts
      - Long term at 100% DC
    - Collector lifetime test setup
      - Major sources of collector degradation
    - Prototype current status
      - Collector lifetime tests
      - Xe recirculation
  - Conclusions

Status of EUV Actinic Reticle Inspection program

Latest Reticle Inspection Solution

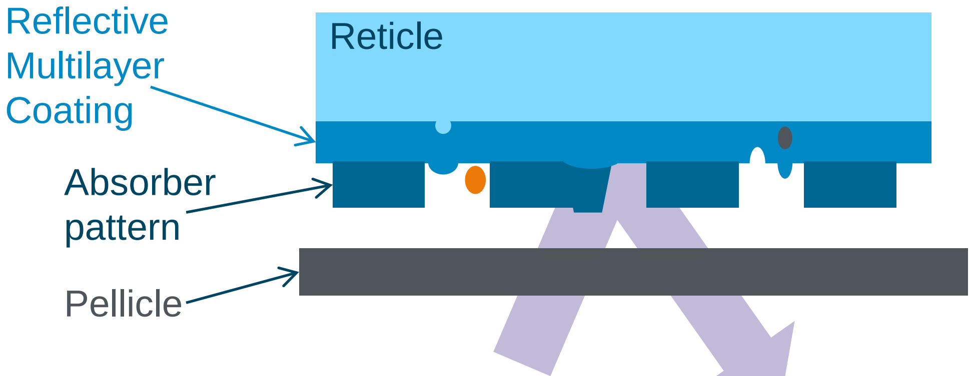
- EUV patterned masks and blanks
- Optical; Complex OPC, Quartz etch reticles
- For ≥ 10nm Generation
- *Practical sensitivity limited by edge roughness*

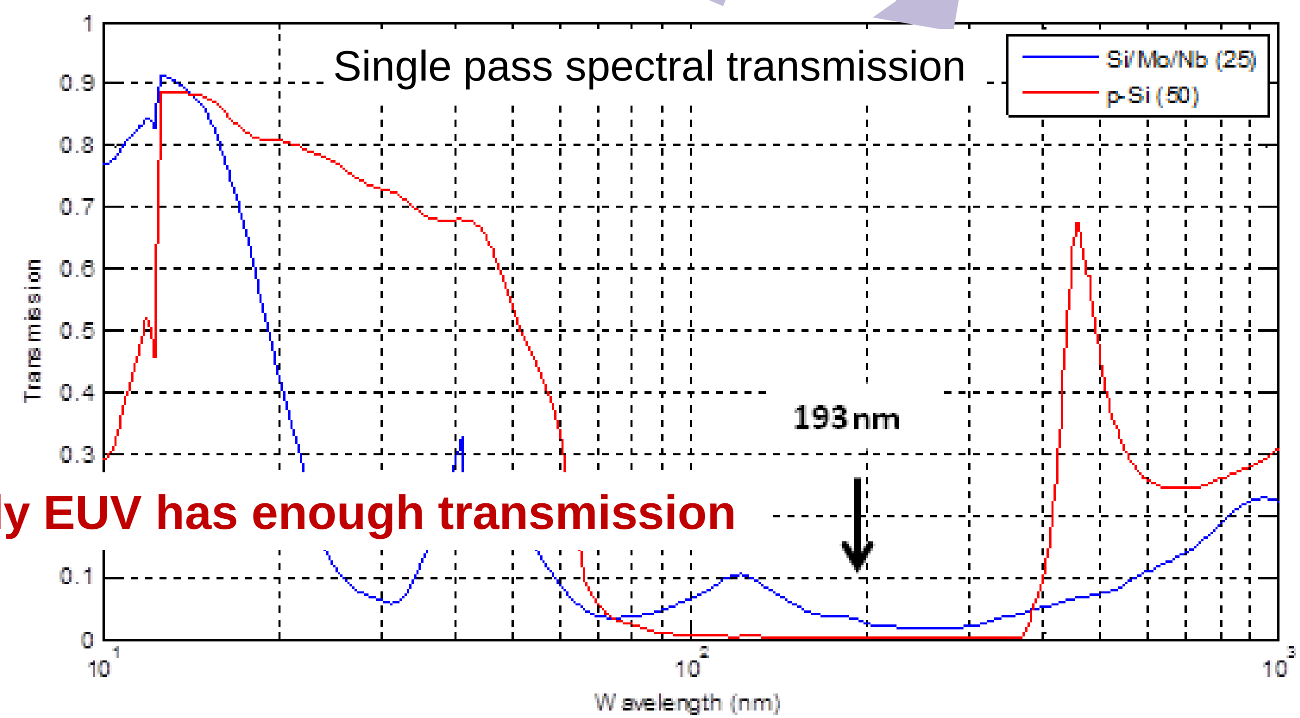
Teron 630

Industry proven sensitivity for advanced optical and EUV Mask applications

EUV Reticle Defect and Inspection Challenges

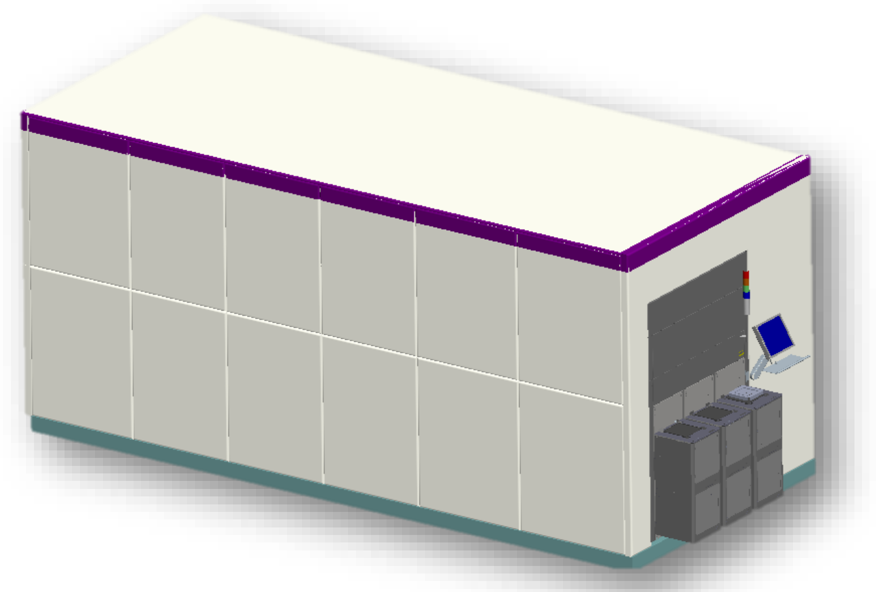
Pellicle transmission effects will narrow the wavelength choices





Only EUV has enough transmission

EUV Actinic Patterned Mask Inspection Tool



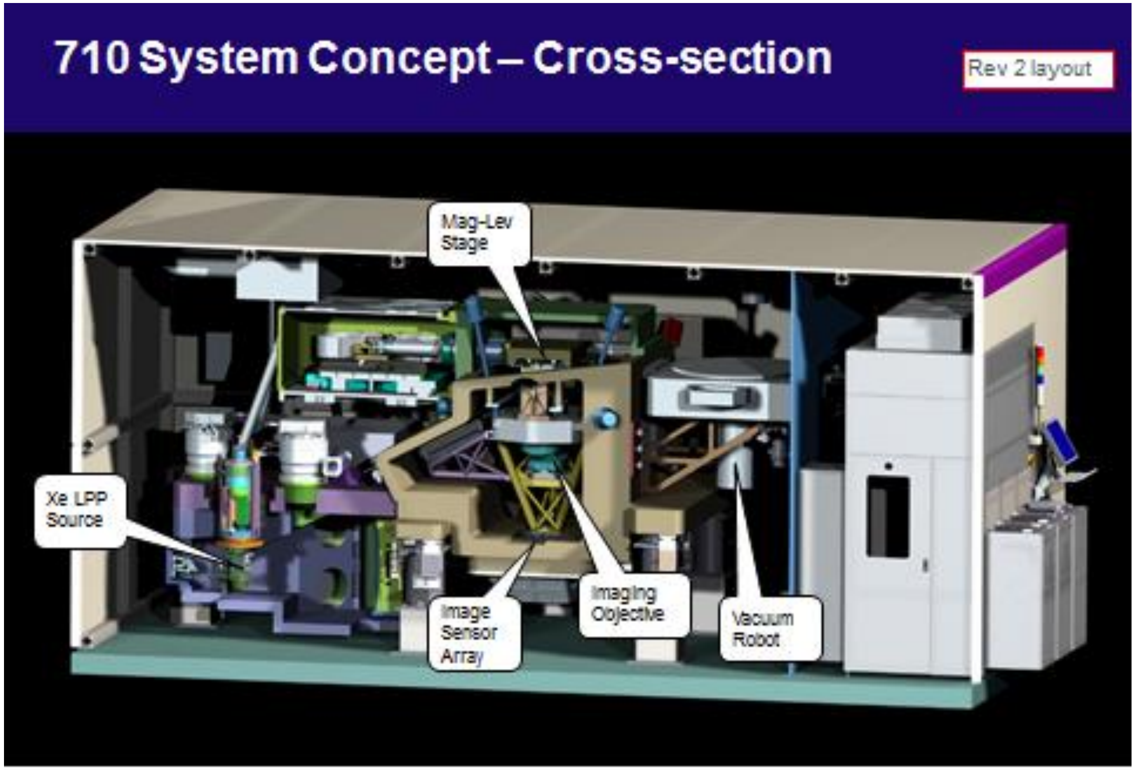
- EUV actinic inspection is a must for EUVL High Volume Manufacturing due to:
  - Phase defects
  - ML Blank defects
  - Contamination defect risks
  - Throughput
  - Through-pellicle inspection

710 Program

The world's only EUV Actinic Patterned Mask Inspection (APMI) System

710 Program Summary

- System Architecture defined
- EUV-specific large format image sensor designed and tested
- Optics concepts provide large field and high transmission
- Xe LPP source prototype shows required lifetime
- Ultra-clean vacuum prototypes tested
- Pilot production facility ready for build-out
- Ongoing new component/subsystem test



Program ready for full-scale development

Xe –based LPP source as bright and reliable solution

Actinic Patterned Mask Inspection
- EUV source requirements

Property/parameter	Target Value	Units
Wavelength	13.5	nm, centroid
Pulse repetition rate	> 10	kHz
Pulse duration	> 10	ns, FWHM
Duty Cycle	> 95%	- minimum burst > 15 sec
Etendue	1.0×10^{-2}	mm^2-sr
Radiance at I/F	> 20	W/mm^2-sr
(Averaged over etendue, lifetime)		2.2% band, pre-SPF
Footprint (m)	2.8W x 2.8D x 2.8H	
Availability	> 95%	
Cost of Service (annual)	< 10%	Relative to CoGs / Price
Cost of Operation (annual)	< 5%	

Options – method of plasma generation

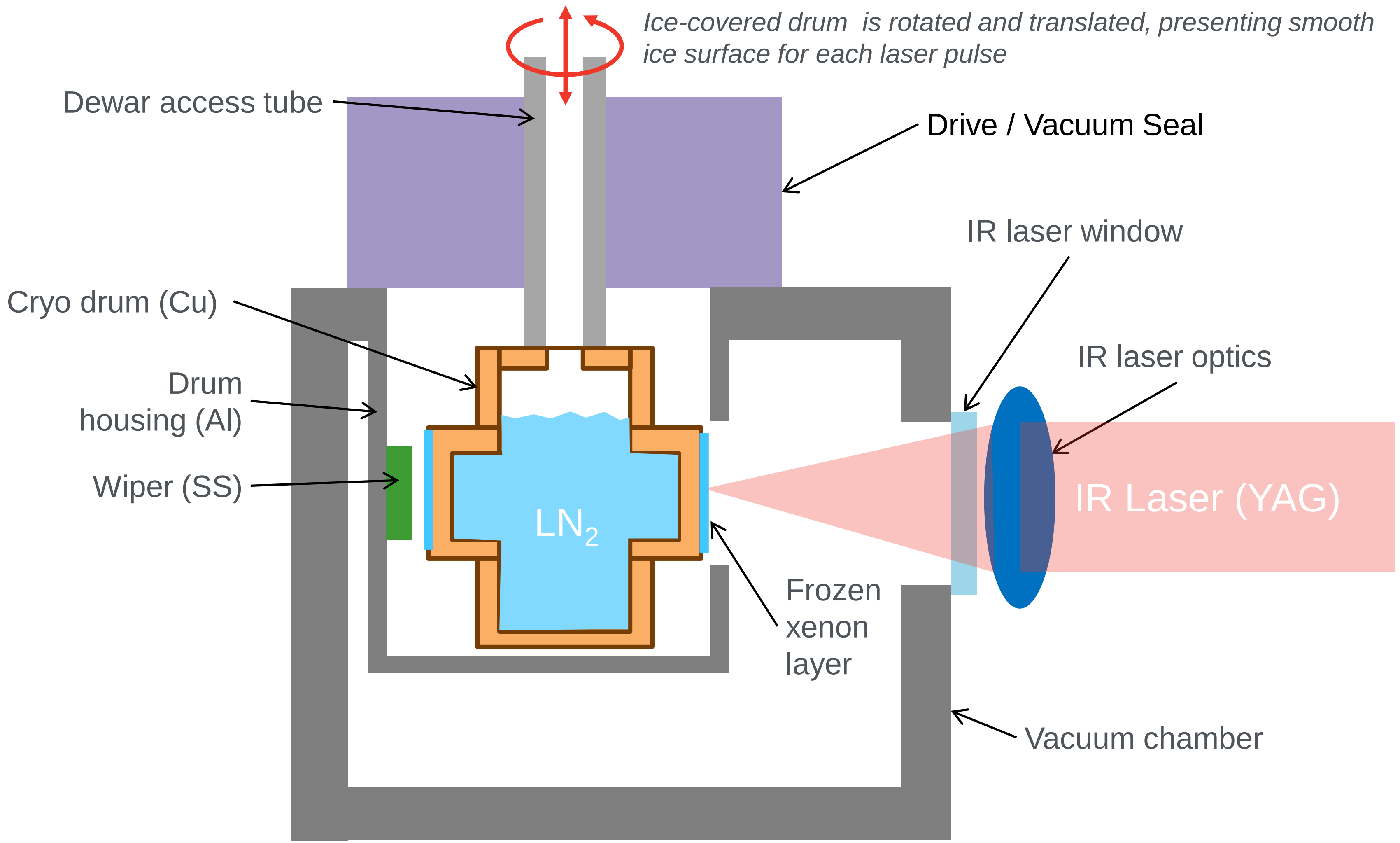
Method	DPP	LPP
Advantages	Simple	Clean Small plasma size Scaling though repetition rate
Disadvantages	Erosion of near-plasma elements Large plasma volume Long plasma Low repetition rate due to pulse power limitations	

Options – choice of target material

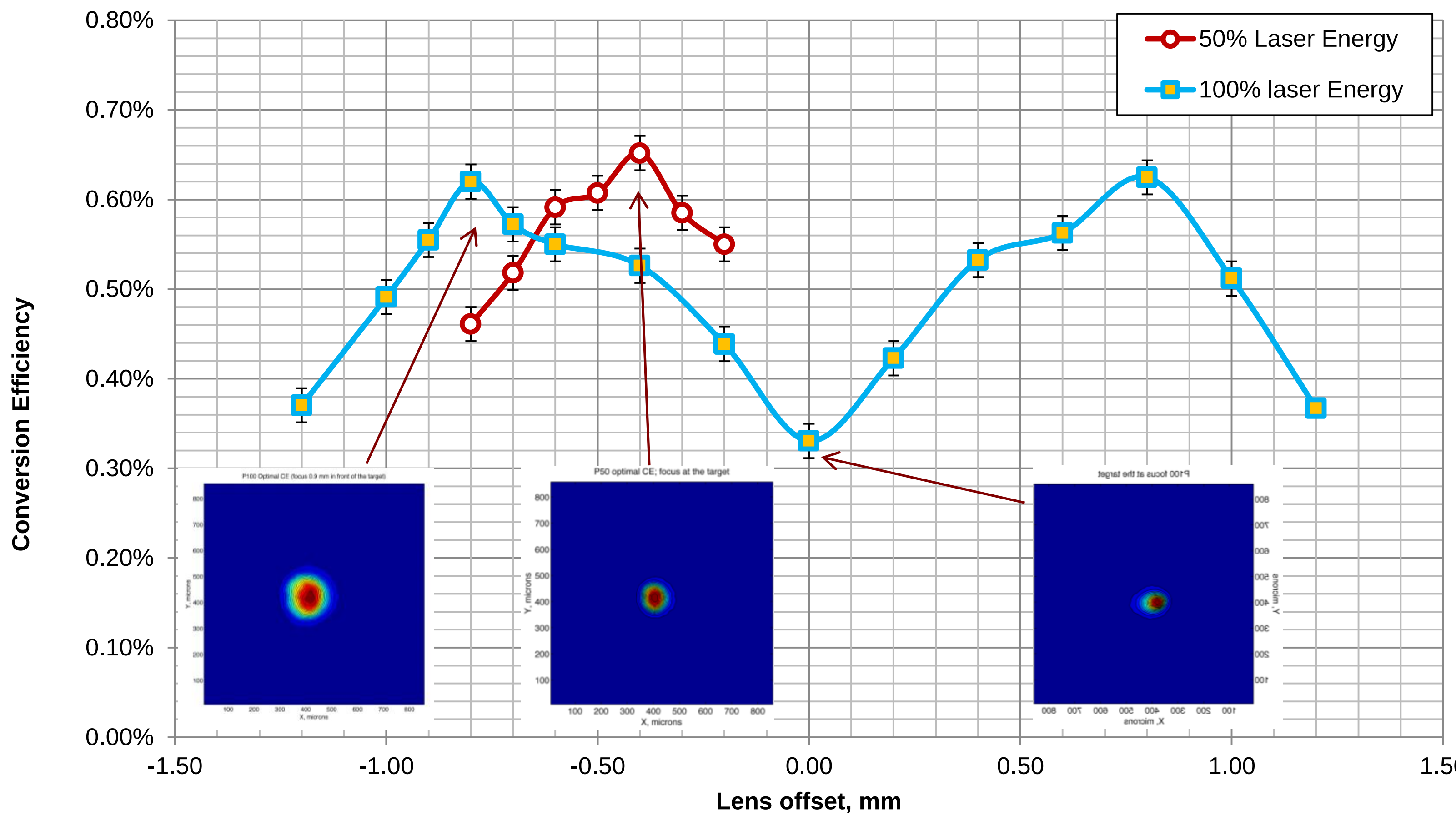
Target	Xe	Sn
Advantages	Noble gas No deposition Can be pumped by off-shell turbo pumps	High CE (>3%)
Disadvantages	Requires closed loop circulation due to high cost of Xe (10-30$/liter)	Deposition Requires mass limited targets Numerous issues with stable and reliable droplet generation Reacts with Ru to form alloys

Cryogenic rotating drum LPP source

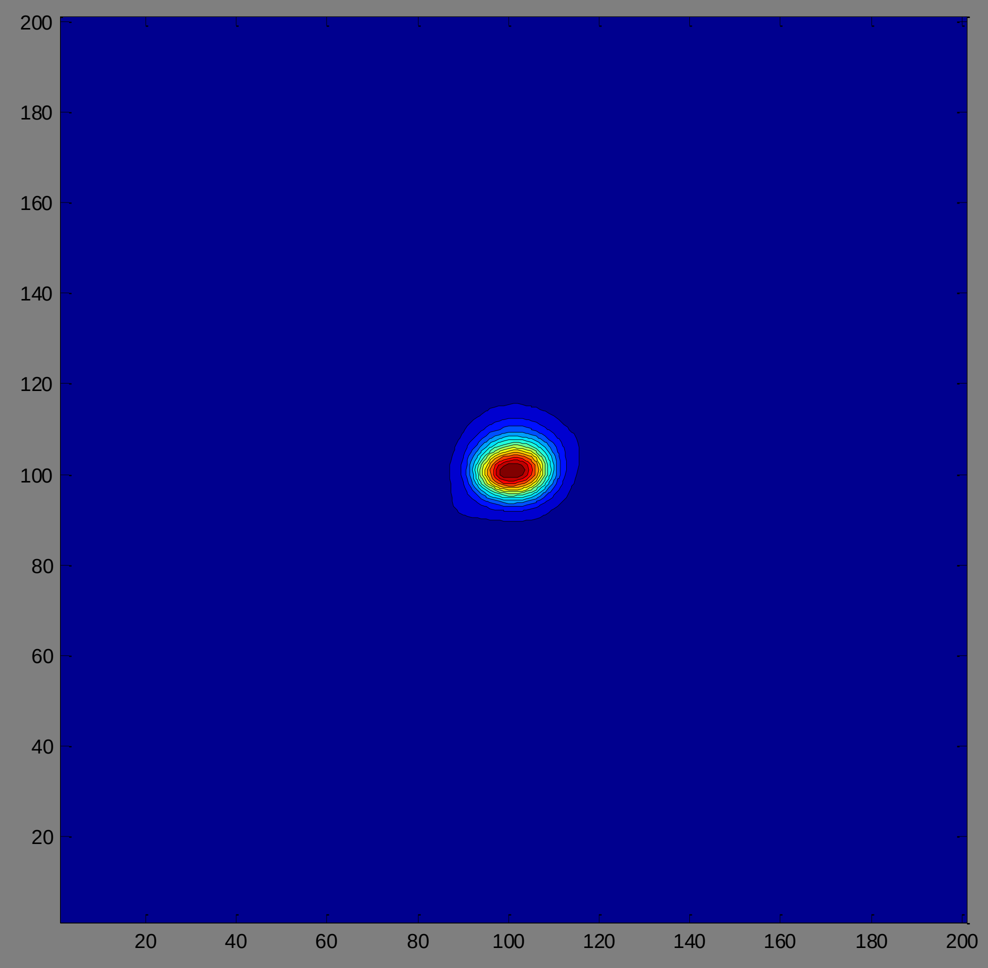
- Schematic of operation

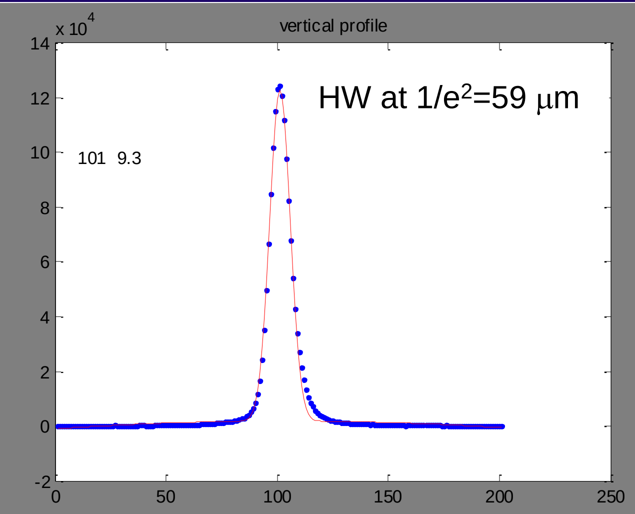


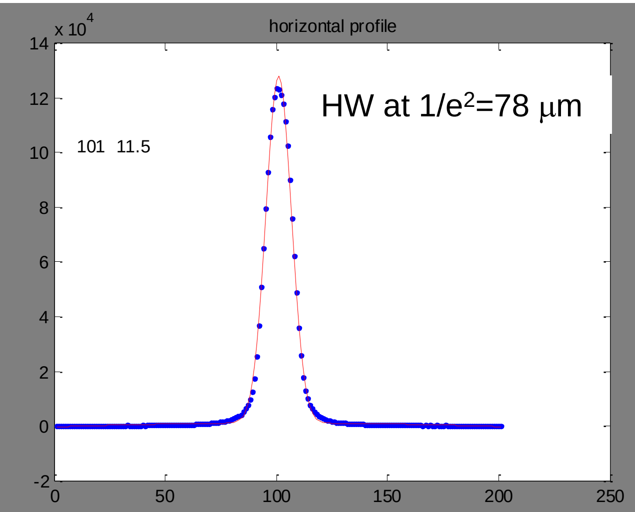
EUV source performance: short bursts



EUV plasma image

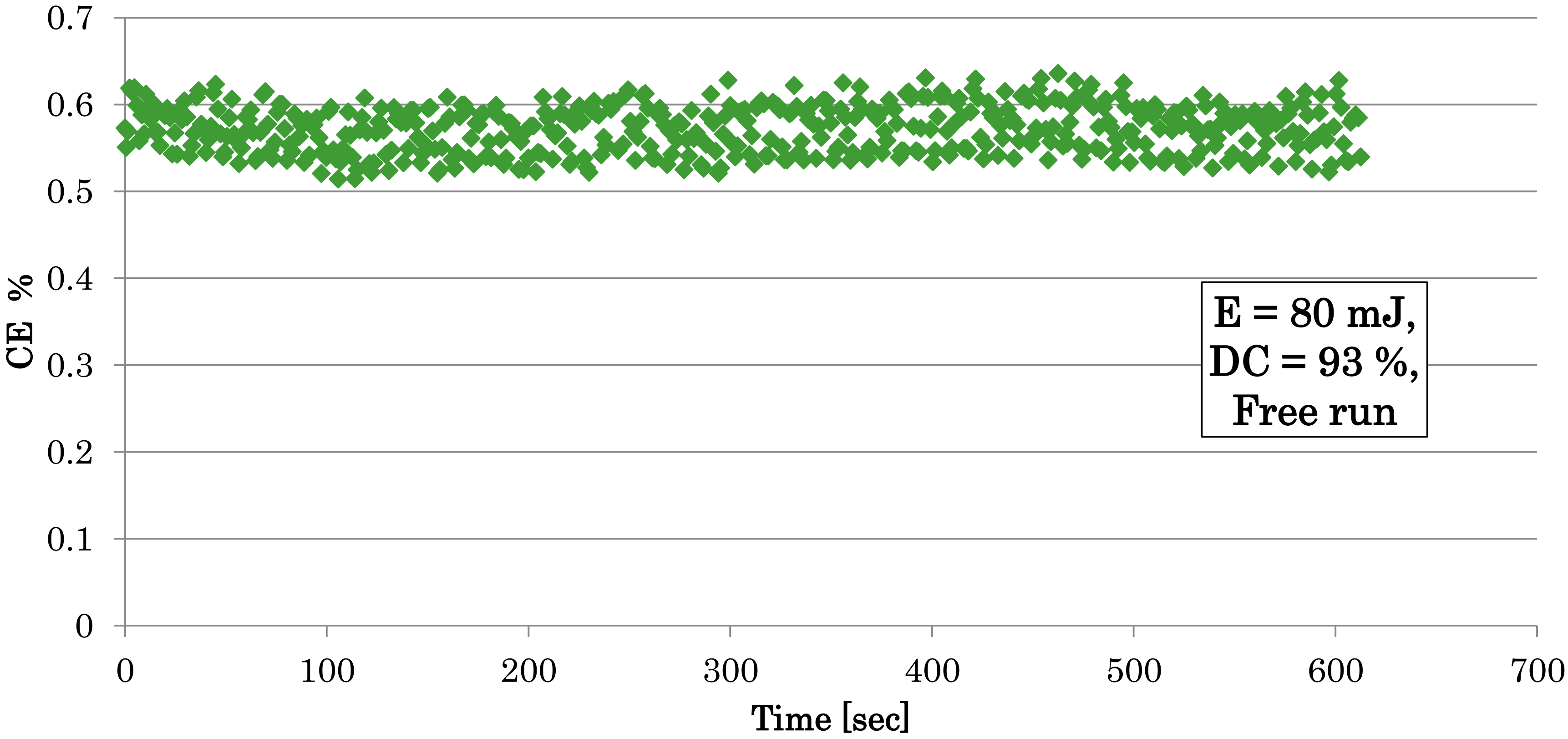






KLA Tencor

Steady state EUV output



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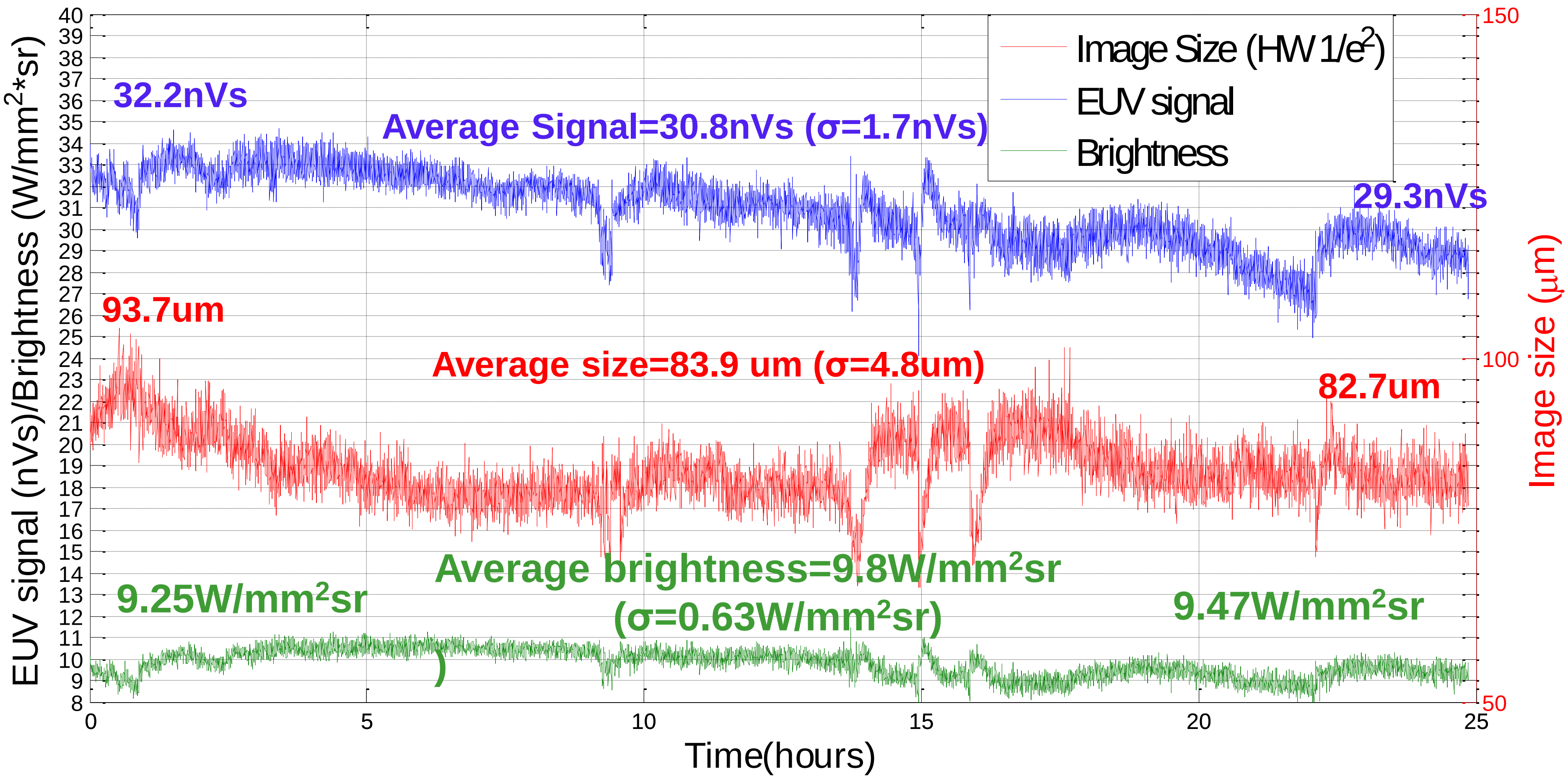
Long term: EUV signal, size, and brightness @ 5kHz



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Primary collector damage mechanism

Energetic ions/neutrals intrinsic to plasma formation

Sputtering of MLM by direct energetic ions has been recorded with >200nm/hours erosions rates at 26cm from plasma

Collector to plasma distance of 0.5-1m is required due to limit of clean pumping solutions.

Sputtering of plasma facing components and chamber walls (too close in LPP 1 setup) & re-deposition of sputtered material on collector

Concept of shower head collector with Ar flow has been successfully tested

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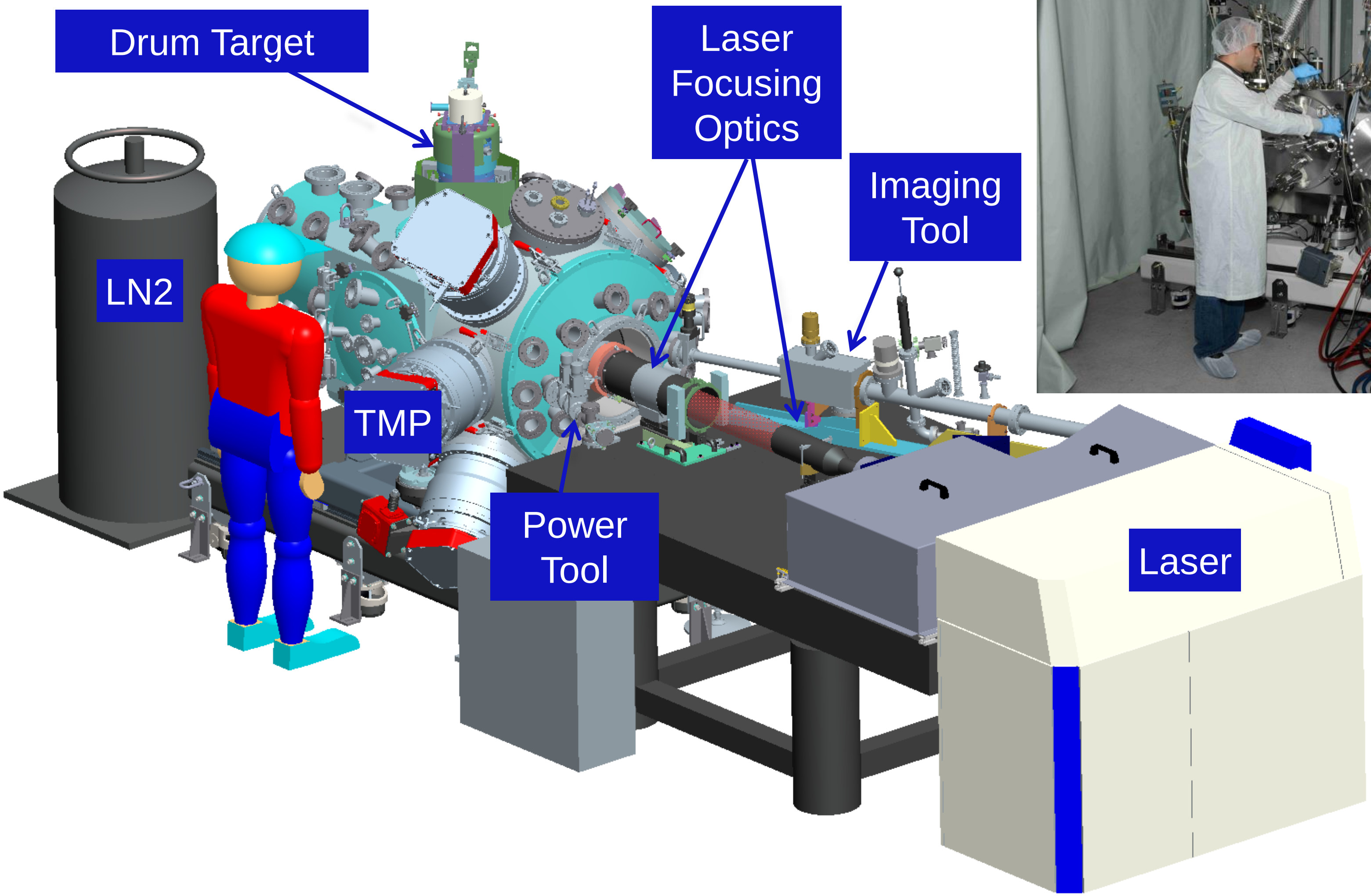
EUV Source Collector Lifetime (CLT) Setup



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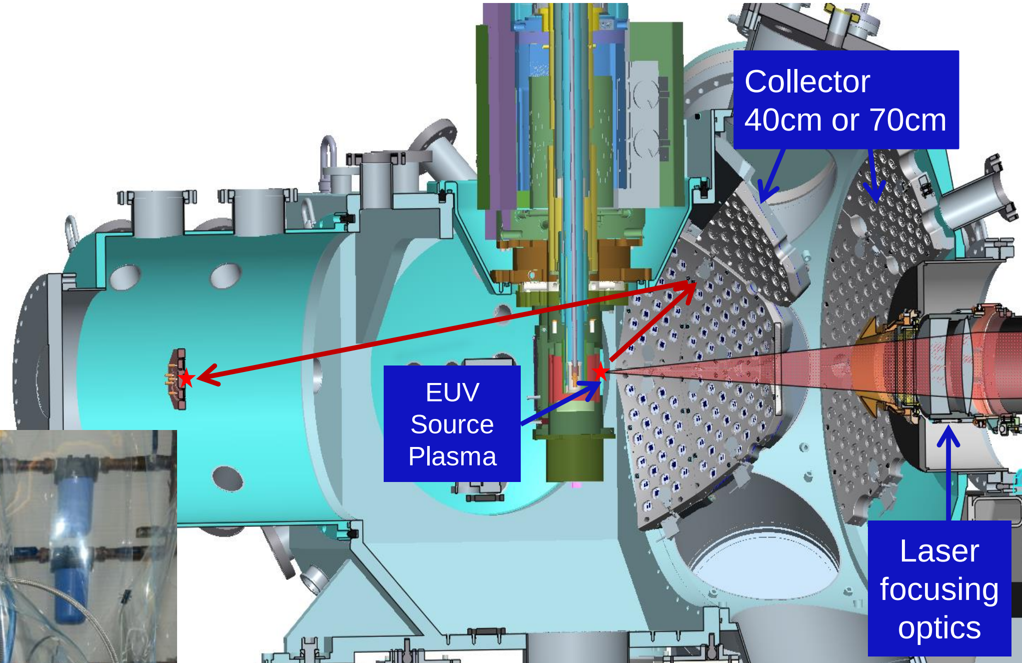
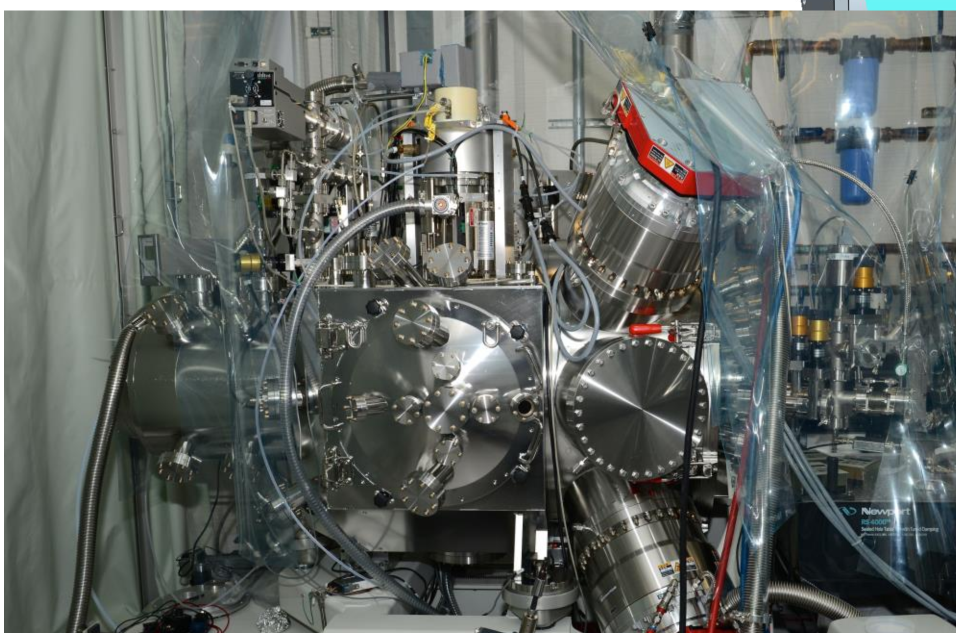
CLT setup details

- Support collector 40-80 cm from plasma
- Advanced protection of collector and laser optic with distributed buffer gas flow
- Flexible debris mitigation capabilities

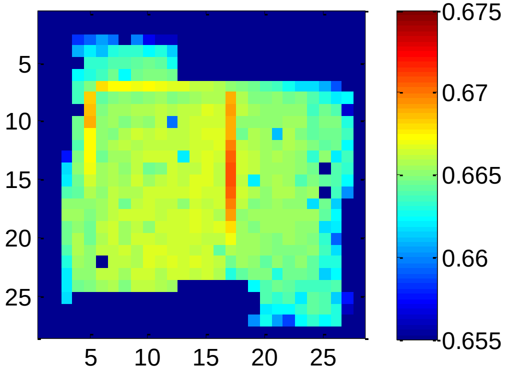


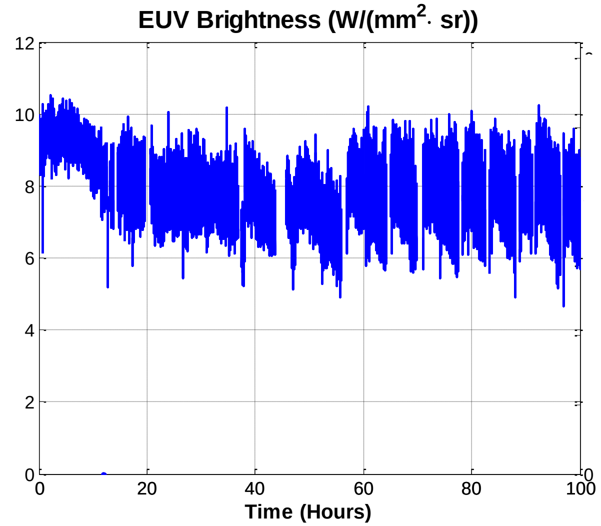


- Plasma –wall distance is > 0.5 m
- Up to 8 turbo-pumps can be installed with total throughput of 16slm
- IF interface ready
- Base pressure is at $2*10^{-8}$torr

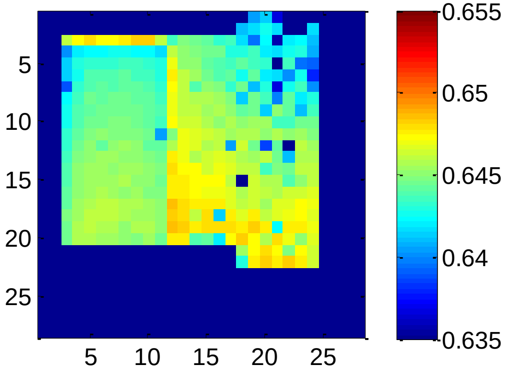
Prototype current status

21-2B52 3nm-Ru-IOF





21-2B51 2.5-Ru-LBL



Duration -120 hours

Effective duty cycle - 80% (limit with current target 92%, manual LN2 and Xe bottles replacement)

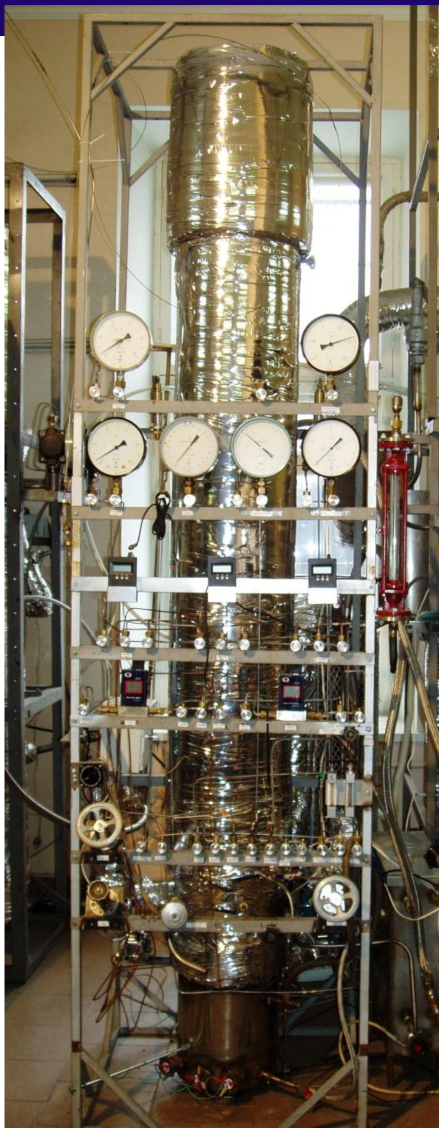
Radiance is at 8W/mm ^{2}sr @5kHz in free run mode

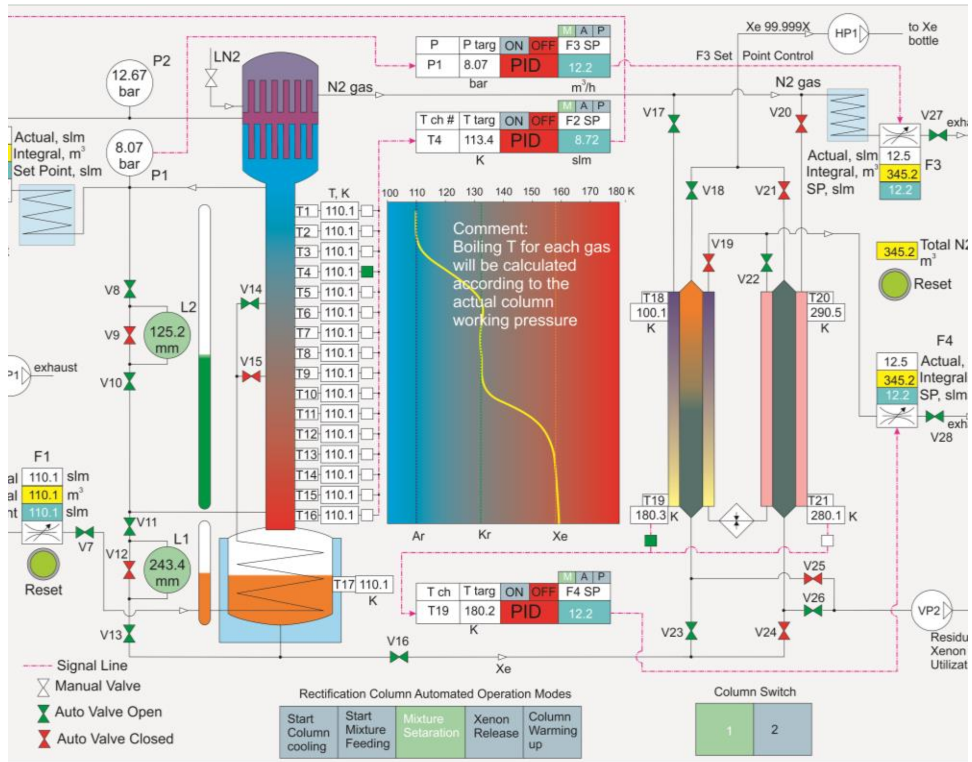
NO reflectivity degradation (within 0.5% accuracy)

Xe Recycling – Development Options

Parameter or Spec	Vendor A	Vendor B	Vendor C
General			
Technology	Distillation and adsorption	Distillation	Multistep adsorption (room temperature, PSA/VSA)
Main products	Rare Gases, Equipment	Rare Gases	Technical Gases
Critical specification parameters			
Recirculation efficiency (RE>98%)	>99%	95%	90%
Xenon Purity (99.999%)	99.999%	>99.999% at 95%RE	>99.9%
Throughput	Demonstrated	Feasible	Up to half of required per system
Contaminations (spec)	Demonstrated	Feasible	TBD
Cost of Recirculation (<$0.6/liter)	<$0.5/liter	>$1.5/liter	TBD
Footprint	$<10m^2$	$50\text{-}100m^2$	$10m^2$
Height	<3m	4.5m	2m

Xe recycle unit development: automatic control





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Conclusions

- Required radiance has been demonstrated at 10kHz in steady state
- Further radiance scaling is possible with faster drum (demonstrated) and repetition rate.
- Major collector degradation mechanisms have been fully characterized
- Effective debris mitigation strategies have been developed and tested
- Full week of operation at 5kHz and 80%DC have been completed with NO collector reflectivity degradation (<0.5%) -> collector lifetime at 10kHz is more than 2000hours.
- Efficient Xe recirculation system has been developed with >99% capture rate Xe and >99.999% Xe purity, which enable cost effective source solution.

Thank You